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A COMPARISON OF THE EFFECTS OF CIRCUIT WEIGHT TRAINING
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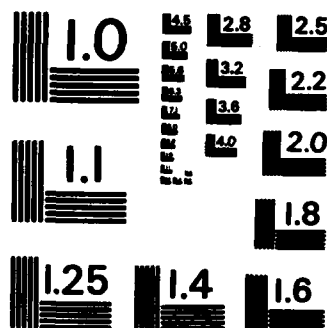
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**A COMPARISON OF THE EFFECTS OF
CIRCUIT WEIGHT TRAINING ON NAVY MEN AND WOMEN**

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SUMMARY

A sample of 29 Navy men aged 22-42 years (\bar{X} age = 33.8 yrs) and 9 Navy women aged 21-36 years (\bar{X} age = 27.7 yrs) participated in a 10-week circuit weight training (CWT) program. During the training period subjects completed three training sessions per week performed on alternate days. Circuit weight exercises were performed on a multi-station (Universal[®]) gym working at an intensity of 40% of estimated one repetition maximum (1RM) strength. Exercise protocol required subjects to exercise for 15 seconds at each station with a 15 second rest period between stations. A total of three circuits were completed each exercise session. To determine fitness changes associated with training, individuals underwent a physical fitness evaluation prior to and following completion of the training period. The evaluation consisted of a battery of tests to measure dynamic and static muscular strength, muscular endurance, stamina, relative body composition, and flexibility.

Findings show stamina and relative body composition measures showed no significant ($p < 0.05$) changes with training. Two-arm lift scores decreased significantly ($p < 0.05$) for women. All other test measures showed significant increases with training. The mean increase for the sum of four upper and two lower torso dynamic strength measures was 13.7% for men and 15.7% for women. Only the arm curl ($F=6.4$) and 2-arm lift test ($F=11.0$) showed significant ($p < 0.05$) training group effects. It can be concluded that circuit weight training demonstrates potential for maintaining the fitness of Navy men and women onboard ship. Circuit weight training stimulates development of muscular strength and muscular endurance required for shipboard work while offering maintenance of aerobic fitness in the absence of running.

INTRODUCTION

Shore-based Navy personnel have traditionally been given the opportunity to participate in a wide variety of athletic activities to develop fitness abilities. The likelihood of Navy personnel encountering a regular physical conditioning program onboard ship however is greatly diminished. Physical constraints imposed by the shipboard environment make the maintenance of fitness while on deployment a difficult undertaking.

While the implementation of physical fitness maintenance programs onboard Navy vessels has always been viewed as necessary, the establishment of functional conditioning programs has for the most part been unsuccessful. To be effective, it appears that shipboard fitness programs should be 1) responsive to critical space restrictions encountered onboard ship, 2) tailored to meet irregular work/rest schedules, and 3) designed to enhance overall shipboard physical readiness. While task analyses conducted by Robertson (1983) have demonstrated a need for upper torso muscular strength for the performance of shipboard work, an optimal shipboard fitness program should also help promote other important components of physical fitness: muscular endurance, cardiorespiratory capacity, flexibility, and relative body composition.

Anticipating the arrival of greater numbers of Navy women onboard ship it would also seem advantageous that an integrated training curriculum be developed from which both Navy men and women could participate and receive maximum benefit. Recently a mode of conditioning termed circuit weight training (CWT) has been found to develop muscular strength and aerobic fitness in men and women by means of brief episodes of weight training on multi-station strength machines (Wilmore, 1978). As an alternative to space demanding running exercises, this method of exercise appears to be highly applicable for use by shipboard personnel. The purpose of this pilot study was to compare fitness responses of Navy men and women following a 10-week program of circuit weight exercises and assess the suitability of this mode of training for maintenance of fitness onboard ship.

MATERIALS AND METHODS

Subjects were 35 Navy men and 15 Navy women stationed at the Naval Training Center, San Diego, CA. All participants were volunteers and each individual filled out an informed consent and privacy act document prior to participation. Due to attrition 29 males and 9 females were able to participate in both the initial and final testing phases of the study. Characteristics of these individuals are presented in Table 1.

TABLE 1 - PARTICIPANT CHARACTERISTICS

	Men		Women	
	Mean	± S.D.	Mean	± S.D.
Age (yrs)	33.8	5.5	27.7	4.2
Height (cm)	177.5	6.9	166.1	4.8
Total Body Weight (kg)	83.1	14.8	65.0	9.6
Lean Body Weight (kg)	65.0	8.0	49.3	4.0
Fat Body Weight (kg)	18.2	8.0	15.7	6.2
% Body Fat	21.1	6.3	23.5	5.7

Training Program: During the training period subjects completed three training sessions per week performed on alternate days. Circuit weight exercises were performed on a multi-station (Universal®) gym working at an intensity of 40% of estimated one repetition maximum (1RM) strength. Exercise protocol required subjects to rotate from station-to-station following a cycle of 15 s of work at a station with 15 s to move to the next station. A total of three circuits were completed each exercise session. The 1RM for the weight exercises was re-evaluated after five weeks of training to adjust for strength changes. The exercise protocol is summarized below:

<u>Frequency</u>	<u>Intensity</u>	<u>Duration</u>	<u>Work/ Rest Cycle</u>	<u>Exercises</u>
3 days/wk (M,W,F)	40% 1RM*	3 circuits	15 s/15 s	†

* 1RM (one repetition max) = maximal weight which can be lifted on a particular exercise.

† Bench press, shoulder press, hip flexor, pull-up, arm-curl, lat-pulldown, leg press, knee extension, arm-dip, sit-up, and handgrip. Women performed leg lifts in place of pull-ups.

Fitness Assessment: To determine alterations in fitness parameters associated with participation in the training programs, individuals underwent a physical fitness evaluation prior to and following completion of the training period. The evaluation consisted of a battery of tests to measure dynamic and static muscular strength, muscular endurance, stamina, relative body composition, and flexibility.

Muscular Strength: Muscular strength (the maximal force which a muscle or set of muscles can generate) of the subjects was determined utilizing both dynamic and static strength measures. Dynamic strength was measured as the 1RM for the following exercises on the (Universal®) gym: bench press, shoulder press, lat-pulldown, arm curl, leg press, and knee extension. One repetition maximum was determined by increasing the loads by single weight plate increments starting from a designated weight value for each exercise. The time allowed between successive trials was that required to readjust the pin which supported the weights (5-10 s).

Static strength of the upper torso was assessed by an isometric 2-arm lift test (Robertson, 1983). The subject was instructed to hold a handle by its side bars and lift while keeping back and legs straight and heels flat on the deck. Chain length was adjusted so that the bottom of the subject's forearm was horizontal to the deck surface with fists vertical and elbows at sides. Two trials were administered to each subject and the mean of the two trials was recorded. Static strength of the arms and shoulder muscles was also assessed by an isometric 1-arm pull test (Robertson, 1983). The subject was instructed to pull a handle while bracing the other hand on a pole. Two trials were performed for each arm and the highest mean arm score recorded.

Muscular Endurance: Muscular endurance (the ability of a muscle or group of muscles to sustain submaximal contractions) was assessed by determining the number of repetitions subjects could perform at 60% of their 1RM for that exercise. Muscular endurance of the upper and lower torso were measured with bench and leg press exercises, respectively. Muscular endurance of the trunk was estimated from the maximum number of bent knee sit-ups an individual could perform within a period of 90 s.

Stamina: Stamina (a combination of aerobic fitness and muscular endurance) was assessed as maximal work capacity on a Monark cycle ergometer based on a protocol developed by a NATO research study group (Myles and Toft, 1982). Subjects were instructed to pedal at a constant rate of 76 RPM against a progressively increasing resistance until volitional fatigue. Warm-up lasted for a period of three minutes at a workload of 228 kpm/min. The workload was then increased 228 kpm/min each min. The greatest workload that the participant could maintain for 50 s was recorded as the measure of physical work capacity.

Relative Body Composition: This component of fitness is defined as the relative amount of the total body weight made up of muscle, bone, and fat. During this investigation each subject was measured for standing height (cm) and body weight (kg). To assess relative body composition, circumference measurements were taken with a fiberglass measurement tape by a single trained tester. The mean of two assessments for each anthropometric site was accepted as the representative value for that site. Percentage body fat was estimated using equations developed for men and women by Wright, et al. (1981). Other parameters of body composition i.e., lean mass and fat mass were calculated from percent body fat.

Flexibility: This component of fitness is defined as the extent of mobility about a joint. Flexibility of the lower back and legs was assessed by a sit and reach test. The subject was seated with legs extended, knees locked, and feet placed against a vertical wood board. A measuring tape was placed on a board at right angles to this board at a height of 35 cm and the subject was instructed to bend forward at the waist with arms and fingers extended as far forward as possible. Three trials were administered to each subject and the largest value recorded.

Analysis Procedures: Differences in fitness changes between men and women were assessed by analysis of covariance (Tatsuoka, 1971). The analysis was performed using the "Statistical Package for the Social Sciences" (Hull and Nie, 1981), with the initial values of the individual fitness measures as covariates. "Adjusted values" (Walker and Lev, 1953) of fitness were determined to remove differences in pre-training fitness measures between groups. In those instances for which analysis of covariance did not yield parallel within-group regressions, Johnson-Neyman regions of significant differences between regression lines were computed (Rogosa, 1981). However in each case where non-parallel regressions were identified, the regions of significant difference lay beyond the range of measured values. As a result the pooled between-group regression coefficients were used in the determination of "adjusted means" for each variable. Within-group pre-post training differences in fitness were assessed using the t-test for correlated means (Linton and Gallo, 1975). Statistical significance was set at $p < 0.05$.

RESULTS

Pre-training fitness scores for males and females are presented in Table 2. Women exhibited 52.6% of male upper torso dynamic strength (sum of bench press, shoulder press, arm curl and lat-pulldown) and 56.5% of male lower torso dynamic strength (sum of knee extension and leg press). Female stamina (measured by bicycle ergometry test) was found to be 65.6% of males.

Percentage change for the various parameters of fitness for men and women are presented in Figs. 1-4. With the exception of female 2-arm lift, all muscular strength and muscular endurance measures showed significant ($p < 0.05$) training effects. The mean increase for the sum of four upper torso and two lower torso dynamic strength measures was 13.7% for men and 15.7% for women. Stamina and all body composition measures were unaffected by training. Only arm curl ($F=6.4$) and 2-arm lift ($F=11.0$) tests showed significant ($p < 0.05$) training effects between men and women.

DISCUSSION

Pre-training physical fitness values reported here are comparable to values observed in other shore-based male (Marcinik et al, 1984a) and female (Marcinik et al, 1984b) Navy populations. A significant difference in both upper and lower torso muscular strength between the sexes is clearly evident. Prior to training, women showed 52.6% of male upper torso and 56.5% of male lower torso strength. The magnitude of this gender related variance agrees with the scientific literature for upper torso, but not lower torso strength. A review by Laubach (1976), for instance, found upper and lower extremity strength of females to be 55.8% and 80.6% that of males respectively.

Despite a considerable gap in initial strength levels, both sexes displayed similar relative strength gains subsequent to training. Wilmore (1978) has reported similar findings in a study

investigating the physiological effects of circuit weight training on the sexes. In our investigation, only arm curl and 2-arm lift test showed significantly different training group effects. Greater relative improvement in arm curl strength by women may be accounted for by the following reasons: 1) the pre-training female arm curl score was 45.7% of the male value. This represents the largest differential in a pre-training strength measure between the sexes. Initial fitness level influences training response and may partially explain this finding (Knuttgen, 1979). 2) Several women with low initial arm curl scores (9.1 kg) performed at a slightly higher workload intensity (50% 1RM) than men (the lowest weight setting on the arm curl station was 4.5 kg). Group differences in 2-arm lift test scores cannot be fully explained. The 2-arm lift test like the arm curl essentially measures biceps muscle strength. It was surprising, therefore, to find that both groups experienced significant gains in arm curl strength yet only women displayed a reduced arm-lift score. This investigation found no significant change in stamina (measured using cycle ergometry) for either sex. A review of the literature, summarized below, shows circuit weight training leads to a general increase of approximately 5% in treadmill determined max $\dot{V}O_2$ (Gettman, 1981).

Study	Sex	N	% $\dot{V}O_2$ Max (ml \cdot kg ⁻¹ \cdot min ⁻¹)
Wilmore, et al. (1978)	M	16	-0.4
	F	12	11.0
Gettman, et al. (1979)	M	16	3.0
Garfield, et al. (1979)	M	10	6.0
	F	12	5.0
Gettman, et al. (1980)	M	13	7.0

Absence of a significant aerobic response following circuit weight training may be attributed to several factors. 1) The most significant difference between this study and prior CWT investigations was duration of exercise. The present CWT curriculum called for 15 s work/rest intervals requiring 16.5 minutes to complete three complete circuits. Previous CWT protocols have required between 22.5 to 34.0 min to complete the exercise regimen. Perhaps an extended exercise period would have resulted in an aerobic improvement. 2) Subjects in the investigation were moderately active individuals many of whom engaged in regular jogging programs. Since aerobic activities were prohibited during the 10 week study period, it appears that circuit weight training did not provide a sufficient training stimulus to promote further aerobic fitness gains beyond initial levels.

With respect to flexibility, analysis of covariance indicated significant gains for both sexes in the sit and reach flexibility test. These findings suggest that strength gains acquired during circuit weight training may not prohibit development of flexibility and may, indeed, enhance range of motion.

No significant change in relative body composition was observed following the 10-week CWT program. These results disagree with the consensus of CWT studies which generally show reductions in percent body fat accompanied by gains in lean body weight (Gettman, 1981). The total work done and

overall energy expenditure of subjects during this investigation was lower than the above mentioned studies and may account for this finding.

A final and unexpected finding was the different rate of attrition between the sexes. Of an initial sample of 35 men and 15 women, 6 men and 6 women attrited (17.1% and 40.0% respectively). The reason for this finding is unclear and warrants further investigation if programs of this type are implemented at the operational level.

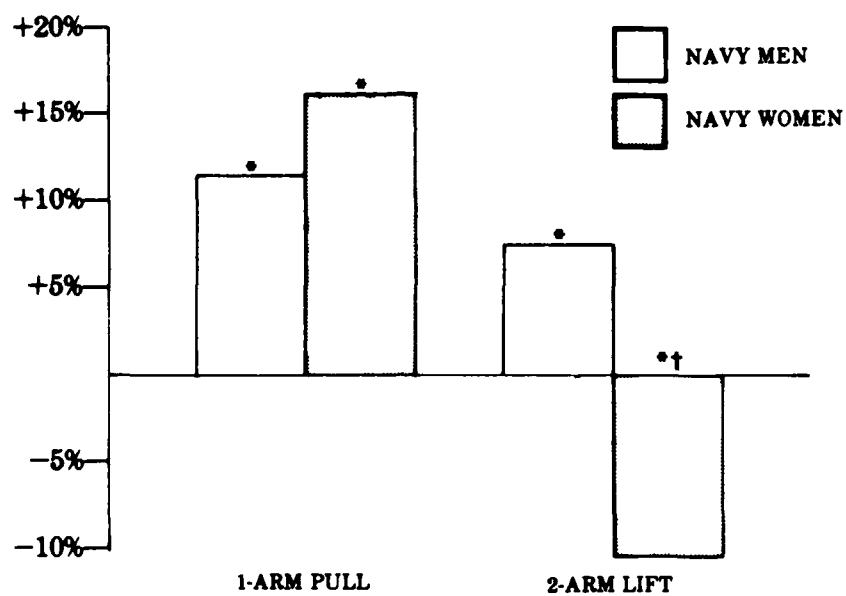
It can be concluded that CWT leads to similar improvements in fitness of Navy men and women. It also results in the muscular strength gains shown to be necessary for shipboard task performance. Aerobic training programs such as running will result in greater improvement in cardiorespiratory capacity than CWT. Circuit weight training however, could help maintain aerobic fitness onboard ship where limited space prohibits running. Future work will investigate the effects of similar CWT programs on performance of muscularly demanding shipboard work.

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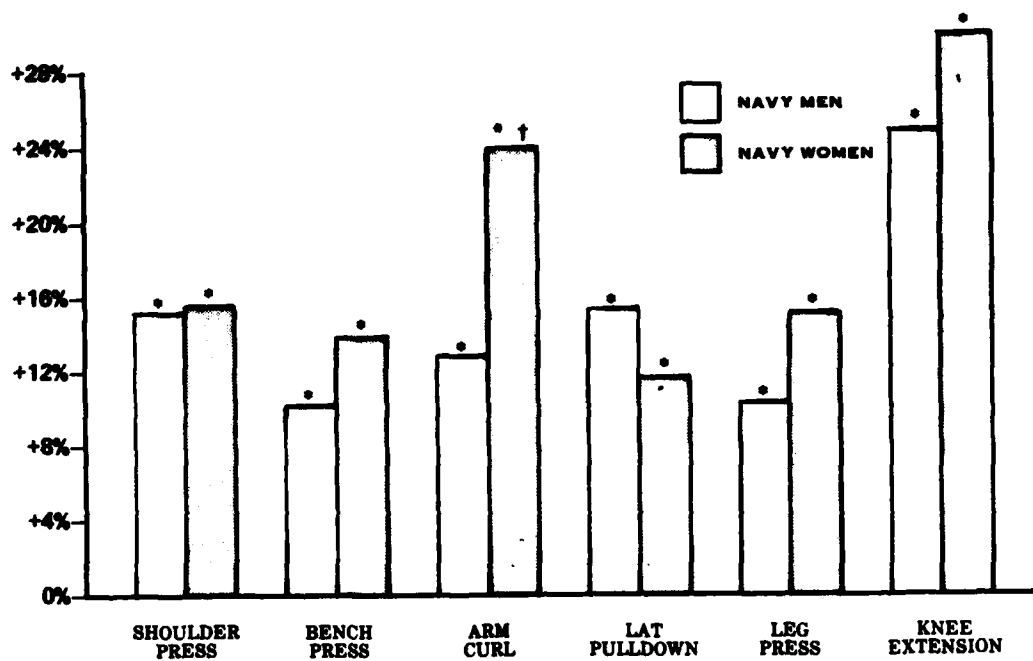
TABLE 2 - PRE-TRAINING FITNESS SCORES FOR NAVY MEN AND WOMEN

Measure	Initial Male Mean	+S.D.	Initial Female Mean	+S.D.	Percent Difference
<u>Upper Torso Dynamic Strength (kg)</u>					
Shoulder Press	44.3	7.4	25.5	2.4	57.6%
Bench Press	53.3	9.3	28.9	5.8	54.3%
Arm Curl	31.0	4.8	14.2	1.6	45.7%
Lat-Pulldown	56.6	6.9	28.9	5.4	51.0%
<u>Upper Torso Isometric Strength (kg)</u>					
1-Arm Pull	63.0	9.0	37.2	7.9	59.1%
2-Arm Lift	43.0	8.5	28.0	6.4	65.1%
<u>Lower Torso Dynamic Strength (kg)</u>					
Leg Press	163.5	23.6	92.3	19.1	57.0%
Knee Extension	47.9	10.2	26.1	9.0	54.4%
<u>Muscular Endurance (No. of Repetitions)</u>					
Bench Press	16.9	4.5	14.0	7.0	82.8%
Leg Press	39.3	13.4	36.7	25.2	93.4%
<u>Stamina (kpm)</u>					
Maximal Work Capacity on Cycle Ergometer	1661.1	276.5	1089.3	249.2	65.6%
<u>Flexibility (cm)</u>					
Sit and Reach Test	1.8	7.6	5.1	4.4	283.3%
<u>Body Composition</u>					
Total Body Weight (kg)	83.1	14.8	65.0	9.6	78.3%
Fat Body Weight (kg)	18.2	8.0	15.7	6.2	86.5%
Lean Body Weight (kg)	65.0	8.0	49.3	4.0	75.9%
% Body Fat	21.1	6.3	23.5	5.7	89.8%



*Significantly different from initial mean value ($p \leq .05$)
†Significant F value ($p \leq .05$)

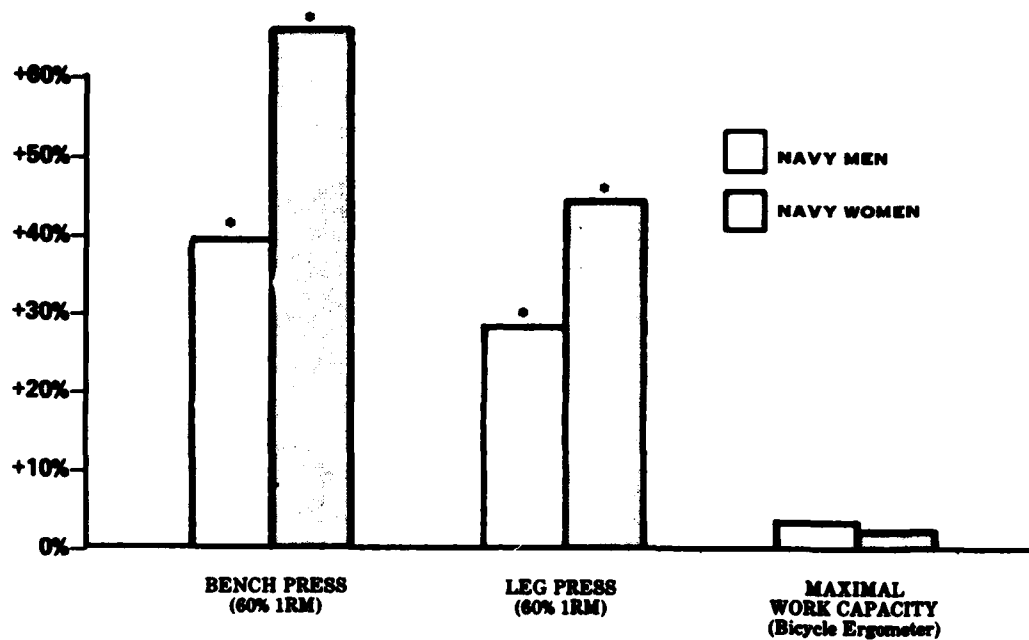
Figure 1. Static strength changes following a 10-week circuit weight training program.



*Significantly different from initial mean value ($p \leq .05$)

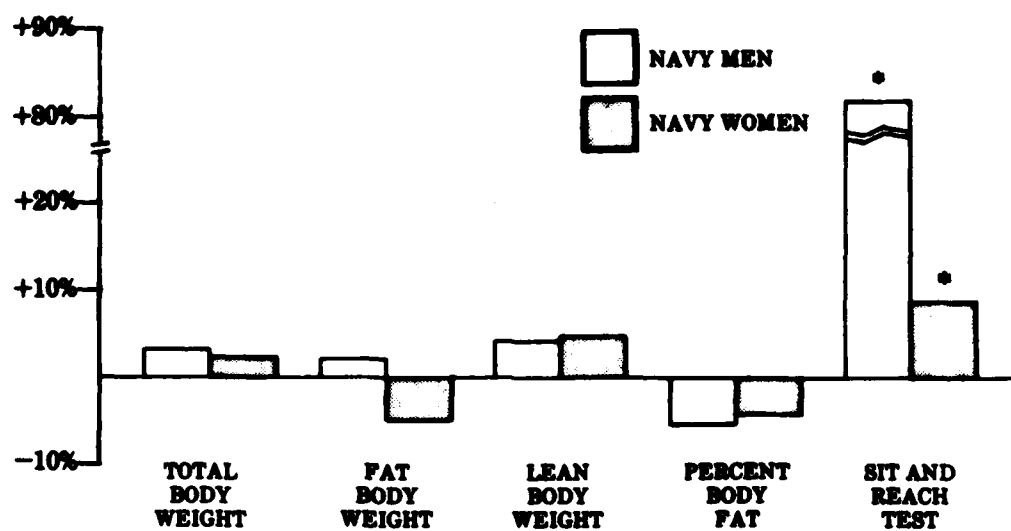
†Significant F value ($p \leq .05$)

Figure 2. Dynamic strength changes following a 10-week circuit weight training program.



*Significantly different from initial mean value ($p \leq .05$)
† Significant F value ($p \leq .05$)

Figure 3. Muscular endurance and stamina changes following a 10-week circuit weight training program.



*Significantly different from initial mean value ($p \leq .06$)

†Significant F value ($p \leq .06$)

Figure 4. Body composition and flexibility changes following a 10-week circuit weight training program.

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<p>(U) Prior to training, women exhibited 52.6% of male upper torso dynamic strength and 56.5% of male lower torso dynamic strength. Both sexes responded in a similar manner to the circuit weight training format. Dynamic muscular strength gains were 13.7% for men and 15.7% women. Stamina and all indices of relative body composition were unaffected by training.</p> <p>It can be concluded that circuit weight training demonstrates a potential for</p>		

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1 shipboard application. It results in the muscular strength gains shown to be necessary for shipboard work performance. It also helps to maintain aerobic fitness in a limited space environment. Keywords:

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